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SOUNDPROOFING OF APARTMENT HOUSES

BY

V. L. CHRISLER, Associate Physicist
Bureau of Standards

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SOUNDPROOFING OF APARTMENT HOUSES

By V. L. Chrisler

ABSTRACT

This paper deals with some of the problems involved in building construction where the attempt is made to prevent sounds passing from one room to another. A theory is presented to show how sound travels through different types of wall and floor construction. Some of the factors which control the amount of sound transmitted are also discussed.

It is pointed out that good heat insulators are not necessarily good sound insulators. In fact, the introduction of heat-insulating material into the air spaces of a partition wall usually increases the amount of sound transmitted because it forms a mechanical tie between the two sides of the partition.

Some suggestions are made showing how the transmission of sound through a partition wall can be reduced by changes in construction.

With the increasing number of apartment houses and office buildings and the consequent concentration of human activities in close proximity, the problem of sound insulation is rapidly becoming one of the first magnitude. In the construction of such buildings increasing attention is being given to the choice of materials and to the type of construction which may be expected to give a satisfactory degree of sound insulation. Until the last few years there has been but little information available on this subject, but recently several laboratories in this country and abroad have given systematic study to the conditions underlying this problem. Among these laboratories the Bureau of Standards is included.

About four years ago the Bureau of Standards constructed a special building for the purpose of making tests of the acoustic properties of building materials, and since then it has tested a large number of partition walls of the types commonly used in building construction. At the present time attention is being directed to various types of masonry walls and floors. It has been gratifying to find that several associations representing the building trades have considered it worth while to cooperate in this program of experimental work. Such cooperation has been available from the Gypsum Industries (Inc.), the National Lime Association, and the Hollow Building Tile Association.

To form a clear idea of the problem of sound insulation it is necessary to consider how the air vibrations which constitute sound waves are transmitted through a partition wall from one room or space to another.

Sound waves in air consist of alternate compressions and rarefactions, and if there are no holes or cracks in the wall to provide an air path along which the waves can pass directly from one side to the other, the only mode of transmission is by setting the wall itself in vibration. The wall yields a very little to the pressure of each sound wave that strikes it, so that it is thrown into a corresponding state of vibration; and the vibrating wall, in turn, sets the air on the other side in motion, just as the diaphragm of a telephone receiver or of a loud-speaker set up sound waves which are then propagated through the air to the listener's ear.

A solid wall or a smaller panel, such as a wooden door, thus acts like a more or less elastic diaphragm held at the edges; and it is obvious that the less the wall moves back and forth in response to the sound waves falling on one side of it, the fainter will be the sound set up on the other side. Hence, making the wall stiffer or heavier, or both, makes it a better sound insulator.

The behavior of compound walls containing inclosed air spaces is not quite so simple, and as an important practical case we may consider the common lath-and-plaster partition supported on studs.

Each face of such a wall consists mainly of a series of rather light and flexible panels, held more or less rigidly at their edges by the studs. The two surfaces are separated by an air space except at the studs, where there is a rigid cross connection which ties the two surfaces together and at these points forces them to move back and forth simultaneously, if at all. Under the alternating pressure impulses of sound waves the studs yield a little and the wall may vibrate as a whole, but each of the more flexible panels may also vibrate separately, its center moving more than its edges, and we may consider what happens to the middle of the panel, disregarding the motion of its edges, for the present.

The surface toward the source of sound is thrown into vibration, and this sets up corresponding sound waves in the dead air space. These throw the second surface into vibration, and so, finally, sound waves are set up in the air on the farther side of the wall. A simpler way to look at it is that the inclosed air acts like an elastic crosstie between the two layers of lath and plaster, but this connection is so weak that the motion of the second surface is very much less than that of the first. The connection is very ineffective, the transmission is low, and the air space is a good insulator.

But if a rigid cross connection is established in the middle of the panel the two surfaces are obliged to move together; and while the

first surface is prevented from moving so much, the second moves very much more, and the net result is that the transmission is increased. Thus, while a single strut or crosstie does not constrain the whole panel, the insulating value of the air space is very much reduced.

If we consider any two adjacent panels together, we may evidently regard the intermediate stud as constituting a rigid crosstie in the middle of a double panel. And although the stiffness and weight of the stud prevent the motion from being as great as if the surfaces were merely connected by a light strip of wood not fastened at the ends, measurements made at the Bureau of Standards show that the transmission of sound through a lath-and-plaster wall does occur mainly at the studs and only to a minor extent across the intervening air spaces.

It is evident from the foregoing that cross connections may be very detrimental to the sound insulating value of a lath-and-plaster wall.

Materials which are fairly good heat insulators are often introduced into this air space, as it has generally been claimed that these materials also improve the sound insulation. The effect of such a filler depends on circumstances. The filler may absorb sound, but it also forms a solid connection between the two surfaces, the connection being more or less soft or rigid according to the material. Moreover, the filler adds to the weight of the wall, and this in itself tends to decrease the vibration of the wall as a whole and to improve the insulation.

The net result could not be predicted, but from the results obtained at the Bureau of Standards it appears that such a filling material is of doubtful value. Although it has been a common assumption with builders that good heat-insulating materials are likewise good sound insulators, experiment does not bear this out in all cases. An air space is generally better than a filling material. In the experiments with stud walls at the Bureau of Standards the introduction of various filling materials into the air space between the studs resulted in nearly every case in a slight increase in the transmission of sound.

These measurements illustrate, also, another point—that weight is not the only factor which determines the sound-insulating property of a wall. For the heaviest heat-insulating material used the sound transmission of the wall was about the same after the wall was filled as before, although the weight of the wall was about doubled, while for the lighter materials, with one exception, the transmission was slightly increased, although the weight had been increased some 50 per cent.

Paul Sabine[1] gives the results of experiments carried out at the Riverbank Laboratories in which he found that either slag or sawdust used as a filler materially reduced the sound insulation of a double partition. The air space in the panels he used was 3 by 8 feet, but the same effect is to be expected in a space 16 inches by 8 feet, the ordinary dimensions of the section between studs in a partition wall.

In other experiments made at the Bureau of Standards, walls were constructed of two solid plaster partitions with an air space occupying the whole area between them. Measurements were taken with the space empty, and also when this space was loosely filled with hair felt, Celotex, and Cabot's Quilt. It was found that although there was but little difference in the amount of sound transmitted in the four cases,[2] the transmission did depend largely upon the manner in which the panels were supported at the edges. For instance, considerably less sound passed through the double panels when they were supported on felt pads than when supported on a piece of wood which acted as a tie between the two partitions.

Experiment, then, leads to these conclusions: First, that to obtain a wall which has the greatest sound-insulating power the two surfaces should not be tied together; and, secondly, that most fillers are valueless or even detrimental as far as sound transmission is concerned, because they act as a tie between the two surfaces. The separation of the surfaces can be accomplished in a masonry wall, where the partition does not carry a load, by building two walls of 3 or 4 inch material with an intervening air space. In a stud wall this can be done by staggering the studs, so that the opposite sides are independently supported. There is a system which has been worked out and used with success by which the weight of the wall surfaces is carried on felt pads. This undoubtedly has some effect in reducing the transmission, although no measurements have been made at the Bureau of Standards on this particular construction.

In old apartment houses there is sometimes a door in the partition between adjoining apartments. This is often a source of annoyance, as the door transmits considerably more sound than the partition.

The defect can be overcome by the use of an auxiliary panel constructed of layers of hair felt between gypsum wall board or Celotex.[3] This auxiliary partition should fit closely in the casing of the door. Gypsum board is more fire resistant than Celotex and slightly more opaque to sound. Whole partitions may be treated in

[1] The Armour Engineer, May, 1926.

[2] Paul Sabine found similar results with hair felt. The Armour Engineer, May, 1926.

[3] Gypsum wall board and Celotex are mentioned, as laboratory tests have been made on these materials. It is probable that some of the other wall boards are equally satisfactory.

this manner, but in such cases it would be better to build a secondary wall, leaving an inch of air space between it and the original partition.

Another source of annoyance is noise in corridors. As corridors are generally built, especially in fireproof structures, the wall surfaces are excellent reflectors of sound. The best of silvered mirrors reflects only 93 per cent of light, while a plastered wall finished with a white coat or a hard sand finish reflects from 97 to 99 per cent of the sound energy. If these surfaces were finished with a plaster which would absorb from 10 to 30 per cent of the sound energy striking it, the corridor noises would be greatly reduced. There are two or three such plasters on the market. It is not only logical but cheaper to use such material in the original construction of a corridor or auditorium rather than to attempt to correct the trouble after the building has been completed.

A sound-absorbing plaster is not necessary for the rooms in an apartment, as the rugs, draperies, furniture, etc., furnish enough absorbing material. In offices, however, when furnished very plainly, such a plaster is desirable to eliminate excessive reverberation.

We have so far dealt only with noises which are communicated to the walls or floors by the air. In the case of noise made by machinery, or by anyone walking across the floor, the problem is of a somewhat different nature. For machinery the only solution is to support the machine on pads, which prevent the vibrations being transferred from the machine to the framework of the building. Various materials, such as cork, hair felt, or other similar materials, have been used for this purpose with varying degrees of success. Great care must also be taken to insulate the holding-down bolts from the machine or building with similar pads, otherwise the vibration would be carried directly to the building, and the pads between the machine and the building would be of no value. In this connection reference may be made to the work of Prof. F. R. Watson, of the University of Illinois.

Floor noises—that is, noises caused by a person walking, dragging a chair across the floor, etc.—can be reduced in somewhat the same manner. In this case either the whole of the finished floor must be supported on pads or cork or rubber tile, or a heavy carpet used on top of the floor, or it is possible to build a suspended ceiling which is insulated from the floor above. By any of these methods the vibrations are to a great extent prevented from reaching the ceiling of the room below. Though several methods have been worked out to reduce noises transmitted in this manner, there have been, as far as the writer knows, no published comparative tests of such systems.

This article must not be taken as a detailed description of how to construct successfully a "soundproof apartment house," but simply as suggesting how improvements to this end may be made. In the successful application of these suggestions the experience and ingenuity of the builder will be a large factor.

Washington, January 6, 1927.